Fertilizer Calculations for Greenhouse Crops

Proper fertilization of greenhouse crops is essential for producing high-quality plants. Some nutrients (such as calcium and magnesium) may be mixed into the growing medium prior to planting, but most of the nutrients are applied after planting using water-soluble fertilizers. **Fertilizer injectors** are used by most growers to apply water-soluble fertilizers to plants. These devices "inject" a small quantity of concentrated fertilizer solution (**stock solution**) into the irrigation line so that the water leaving the hose (**dilute solution**) supplies the proper concentration of fertilizer. Applying fertilizers in a liquid form with a fertilizer injector is more convenient than broadcasting or top-dressing with dry fertilizers. Additionally, most growers apply water-soluble fertilizers at a dilute concentration on a "constant feed" basis (with every watering) to insure an adequate supply of the essential elements for plant growth.

Rates of fertilization are often given in **parts per million (ppm) of nitrogen (N)**. Parts per million is a convenient unit of measurement for indicating the concentration of fertilizer solutions. For example, it is often recommended that 150 to 250 ppm N be applied in the irrigation water on a "constant feed" basis for fertilizing many floricultural crops. But what actually does this mean? If we use a fertilizer such as 20-20-20 with 20% nitrogen, 13½ ounces are needed to make 100 gallons of a 200 ppm N solution, whereas with a 15-15-15 fertilizer containing 15% nitrogen, 18 ounces are required to make 100 gallons of a 200 ppm solution. Thus, the advantage of parts per million terminology is that we can state the concentration of a fertilizer solution **independent** of the fertilizer analysis. This is important for standardizing fertilizer recommendations since the percentage of nitrogen varies markedly among the water-soluble N-P-K fertilizers sold commercially.

Fertilizer stock solutions are mixed according to the **fertilizer injector ratio**: each injector will deliver a certain amount of stock solution for each increment of irrigation water that passes through the injector. For example, a 1:100 injector will deliver 100 gallons of dilute fertilizer solution for each gallon of concentrated stock solution. A 1:200 injector will deliver 200 gallons of dilute fertilizer for each gallon of concentrated stock solution (or 100 gallons of dilute solution per ½ gallon of stock). If both injectors were to deliver 200 ppm of nitrogen from the same fertilizer, the stock solution for the 1:200 injector would have to be **twice as concentrated** as the one for the 1:100 injector. Thus, the injector ratio determines the **concentration of the stock solution** that is needed to deliver a particular rate of fertilization. Some injectors (Hozon, Smith Measuremix) have a **fixed** (nonadjustable) injector ratio whereas other injectors (Anderson, Dosmatic, Dosatron, M-P Mixer Proportioner) have **adjustable** ratios. Many growers prefer injectors with adjustable ratios so that different fertilizer rates can be applied to crops with different nutrient requirements.

The preparation of fertilizer stock solutions is of paramount importance. Growers must accurately determine the amount of fertilizer needed to mix stock solutions of fertilizers. Most of the manufacturers of commercial fertilizers and fertilizer injectors have produced tables that simplify this task. Information is also provided on fertilizer bags. Without recourse to tables or bags, growers can use formulas to calculate the amount of fertilizer needed. If you know the rate of fertilization (in ppm N), the percentage of nitrogen in the fertilizer, and the injector ratio, then calculations are simplified by the following formula:

$$\text{Amount of fertilizer to make 1 volume of stock solution} = \frac{\text{Desired concentration in parts per million} \times \text{Dilution factor}}{\text{\% of element in fertilizer} \times C}$$

where the dilution factor is the larger number of the fertilizer injector ratio and the conversion constant C is determined by the units desired:

Unit	Conversion constant
Ounces per U.S. gallon	75
Pounds per U.S. gallon	1200
Grams per liter	10

This formula allows you to easily calculate the amount of fertilizer needed to mix stock solutions. The beauty of this formula is that it can be used with any fertilizer injector and all common units of measurement.

The table above lists conversion constants for a number of units. Growers usually prefer fertilizer recommendations in ounces (or pounds) of fertilizer per gallon. A metric conversion constant is provided for those brave few who have made the switch from the English system of measurement.

Stock solution Calculations

Example 1. You have a 1:200 fertilizer injector and a fertilizer with an analysis of 15-16-17 (%N-%P2O5-%K2O). You want to apply a 250 ppm solution of nitrogen at each watering. How many ounces of fertilizer would you have to weigh out to make **1 gallon** of concentrate?

A. To solve the problem:

1. List all the variables:
a. Desired concentration in parts per million (ppm) = 250.
b. Injector ratio = 1:200; dilution factor = 200.
c. Fertilizer analysis = 15-16-17 (15% N).
d. Ounces of fertilizer to make 1 gallon of concentrate = X (unknown). Use 75 as the conversion constant C.

2. Set up and solve the problem

$$X = \frac{250 \text{ ppm N} \times 200}{15\% \text{ N} \times 75} = \frac{50{,}000}{1{,}125} = 44.44 \text{ (about } 44\tfrac{1}{2} \text{ oz./gal.)}$$

B. Answer: add 44½ ounces of 15-16-17 to a stock solution bucket and fill to the 1 gallon mark.

Many growers do not have access to an accurate scale for weighing fertilizers. Since most commercially formulated N-P-K fertilizers are packaged in 25-pound bags, we can easily determine how many gallons of stock solution to mix up from 1 bag of fertilizer:

1. Convert 25 pounds into the equivalent amount of ounces:

25 pounds/bag x 16 ounces/pound = 400 ounces/bag

2. Using the information in Example 1, we then divide 400 by 44½ to get the number of gallons of stock needed:

400 ounces/bag 44½ ounces/gallon = 8.99 (**about 9 gallons/bag**)

Thus, one 25-pound bag of 15-16-17 fertilizer will make 9 gallons of stock for a 250 ppm N solution when using a 1:200 injector.

It is important to remember that the final volume of stock solution should be 9 gallons, and this means we add the fertilizer first and then add water (warm water works best) for a final volume of 9 gallons. Adding the bag of fertilizer to 9 gallons of water will give us more than 9 gallons of stock and thus a more dilute stock solution than desired.

Example 2. You have a fertilizer injector with a 1:100 ratio and are using a 25-10-10 (%N-%P2O5-%K2O) fertilizer. You want to apply a 450 ppm solution (based on nitrogen). How many **pounds** of fertilizer would you have to weigh out to make **10 gallons** of concentrate?

A. To solve the problem:

1. List all the variables to find out what is known and unknown:

a. Desired concentration in parts per million (ppm) = 450.
b. Injector ratio = 1:100; dilution factor = 100..
c. Fertilizer analysis = 25-10-10 (25% N).
d. Pounds of fertilizer to make 1 gallon of concentrate = X (unknown). Use 1200 as the conversion constant C.
e. 10 gallons of concentrate are needed.

2. Set up the problem to solve for 1 gallon of concentrate:

$$X = \frac{450 \text{ ppm N} \times 100}{25\% \text{ N} \times 1200} = \frac{45{,}000}{30{,}000} = 1.5 \text{ lbs./gallon}$$

3. Next, solve the problem for 10 gallons of concentrate:

1.5 pounds/gallon x 10 gallons = 15

B. **Answer:** add 15 pounds of 25-10-10 to a stock solution bucket and fill to the 10 gallon mark.

Complete (N-P-K) fertilizers always contain nitrogen, potassium, and phosphorus, and may also include other essential secondary or minor elements. Fertilizers are distinguished by three numbers, such as 20-20-20 or 15-16-17. The first, second, and third numbers indicate the percentages of elemental nitrogen (N), phosphorus in the oxide form (P2O5), and potassium in the oxide form (K2O), respectively. We can use the simple rule, "Percent K and percent P equals 1.2 and 2.3," to convert from oxide to the elemental forms for phosphorus and potassium, that is, from %P2O5 to %P and from %K2O to %K.

Example 3. You have a fertilizer with an analysis of 20-20-20 (%N-%P2O5-%K2O). What is the percentage of phosphorus and potassium in the elemental form?

A. To solve the problem:

1. List all the variables to find out what is known and unknown:

a. Fertilizer analysis = 20-20-20 (20% P2O5 and 20% K2O).
b. Conversion rule: "%K and %P equals 1.2 and 2.3."

2. Set up the problem:

$$\%P = \frac{\%P_2O_5}{2.3} = \frac{20}{2.3} = 8.7\% \text{ phosphorus in 20-20-20}$$

$$\%K = \frac{\%K_2O}{1.2} = \frac{20}{2.3} = 16.7\% \text{ potassium in 20-20-20}$$

Answer: 20-20-20 contains 8.7% elemental phosphorus and 16.7% elemental potassium.

The conversion rule is useful when we desire to fertilize with simple fertilizers such as potassium nitrate (13-0-44). When plants are grown in media which contain adequate levels of phosphorus (for example, from a pre-plant addition of superphosphate), it is often recommended that 200 ppm of N and K be applied at each watering. We can achieve this fertilization program using potassium nitrate and calcium nitrate (15.5-0-0). We can use the formula previously given to calculate ppm K if we first convert from the oxide to the elemental form.

Example 4. You have a 1:100 injector and want to use potassium nitrate (13%N-0%P2O5-44%K2O) and calcium nitrate (15.5%N-0%P2O5-0%K2O) to supply 200 ppm of N and K with each watering. How many **ounces** of each fertilizer would you have to weigh out to make **1 gallon** of concentrate?

A. To solve the problem:

1. List all the variables to find out what is known and unknown:

a. Desired concentration in parts per million (ppm) = 200 N and K.
b. Injector ratio = 1:100; dilution factor = 100.
c. Fertilizer analyses = 13-0-44 and 15.5-0-0.
d. Ounces of each fertilizer to make 1 gallon of concentrate = X (unknown). Use 75 as the conversion constant C.

2. First, convert %K2O to %K for potassium nitrate:

$$\%K = \frac{\%K_2O}{1.2} = \frac{44}{1.2} = 36.7\% \text{ potassium in 13-0-44}$$

3. Potassium nitrate supplies both potassium and nitrogen, whereas calcium nitrate supplies only nitrogen. Figure out how much potassium nitrate is needed to supply 200 ppm K:

X= <u>200 ppm K x 100</u> = <u>20,000</u> = 7.26 (about) 7.3

36.7%K x 75 2752.5 oz./gal.

4. Next, figure out the ppm N supplied when 7.3 ounces of potassium nitrate is dissolved per gallon of stock. Potassium nitrate supplies 36.7% elemental potassium and 13% elemental nitrogen. The ratio of elemental potassium to elemental nitrogen **remains the same**, regardless of whether the fertilizer is in solid form or dissolved in water. This relationship also holds true for other fertilizer salts. Therefore:

$$\frac{13\%\ \text{N}}{36.7\%\ \text{K}} = \frac{\text{X ppm N}}{\text{200 ppm K}}$$

36.7 X = 2600

X= 2600 ÷ 36.7 = 70.8 = (about) 71 ppm N supplied by potassium nitrate.

5. Since we desire 200 ppm N and potassium nitrate supplies only 71 ppm N, we must make up the rest of the nitrogen with calcium nitrate. Therefore:

200 ppm N - 71 ppm N = 129 ppm N needed from calcium nitrate.

6. Lastly, determine the amount of calcium nitrate needed to supply 129 ppm N:

$$X = \frac{\text{129 ppm N x 100}}{15.5\%\ \text{N x 75}} = \frac{12{,}900}{1162.5} = \text{11.1 oz./gal.}$$

B. **Answer:** add 7.3 ounces of potassium nitrate and 11.1 ounces of calcium nitrate to a stock solution bucket and fill to the 1 gallon mark. This will supply 200 ppm of N and K with each watering when using a 1:100 injector.

With the aid of a hand-held calculator, you can easily determine the proper amount of fertilizer for making stock solutions. Remember, always recheck your calculations to insure they are correct: errors may be **very costly**!

Fertilizer injector ratios may change over time, so growers should periodically determine the fertilizer injector ratio to avoid nutritional problems. There are two methods for determining the injector ratio. The most common method is to simultaneously measure the volume of stock solution taken up (= Vstk) and the volume of dilute solution that is delivered (= Vdil) and then dividing Vdil by Vstk. For example, if five gallons of dilute solution were produced and 6 fluid ounces of stock were taken up, then the injector ratio would be:

(5 gallons x 128 fluid ounces) ÷ 6 ounces = 640 ÷ 6 = (about)107 = 1:107 injector ratio

The second method would be to measure the electrical conductivity (EC) of the dilute fertilizer solution. Fertilizer manufacturers supply EC values for each fertilizer they produce and the information is provided on the fertilizer bag or in supplemental sheets. The EC of the dilute solution minus the EC of the raw irrigation water should be equal to the EC level listed by the manufacturer for the concentration of fertilizer that is being applied. For example, assume that a grower is applying calcium nitrate (15.5%N-0%P2O5-0%K2O) at 200 ppm N using a fertilizer injector that is assumed to be 1:100. First, calculate the amount of calcium nitrate to prepare one gallon of stock solution:

$$X = \frac{200 \text{ ppm N} \times 100}{15.5\% \text{ N} \times 75} = \frac{20,000}{1162.5} = 17.2 \text{ oz./gal.}$$

The stock solution is prepared and then EC values are determined. The dilute solution EC is 2.25 mmho/cm and the irrigation water EC is 0.53 mmho/cm. Therefore the EC attributable to calcium nitrate is 2.25 - 0.53 = 1.72 mmho/cm. According to the fertilizer manufacturer, the EC value for calcium nitrate at 200 ppm N should be 1.48 mmho/cm. We can calculate the actual concentration of calcium nitrate in the dilute solution by setting up a proportion:

$$\frac{200 \text{ ppm N}}{X \text{ ppm N}} = \frac{1.48}{1.72}$$

1.48X = 200 x 1.72

1.48X = 344

X = 344/1.48 or 232 ppm N

The dilute fertilizer solution exceeds the expected value by 32 ppm (= 232 - 200) . The equation that was used earlier can be used to determine the actual injector ratio. This time, however, the fertilizer injector ratio is the unknown variable (= X):

$$17.2 \text{ ounces/gallon} = \frac{232 \text{ ppm N} \times X}{15.5\% \text{ N} \times 75}$$

$$17.2 \text{ ounces/gallon} = \frac{232 X}{1162.5}$$

19995 = 232X

X = 19995 ÷ 232 = 86.2

Thus, the actual injector ratio is approximately 1:86.

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